WE CLAIM:

1. A substrate processing system comprising:

a source of a carrier gas;

a support medium having a surface onto which a solid source for vapor reactant is coated, the support medium being configured to guide the carrier gas through the support medium, the coated support medium collectively forming a bed, the source of carrier gas being connected upstream of the support medium; and

a reaction chamber connected downstream of the support medium.

2. The system according to Claim 1, wherein the support medium is configured to remain substantially stationary during the saturation of the carrier gas.

3. The system according to Claim 1, wherein the reaction chamber is an atomic layer deposition (ALD) chamber.

4. The system according to Claim 1, wherein the support medium is configured to guide the carrier gas in a convoluted contact path.

5. The system according to Claim 1, further including a sublimation vessel, located downstream of the carrier gas source and upstream of the reaction chamber, the support medium being located in the vessel, the solid source coating having a ratio of total exposed surface area to bed volume greater than about 0.1 cm^{-1}.

6. The system according to Claim 1, wherein the bed is formed from a plurality of packed flowable support elements.

7. The system according to Claim 1, wherein the support medium has a shape selected from a group consisting of beads, rings, cylinders, and filaments.

8. The system according to Claim 1, wherein the solid source coating has a ratio of total exposed surface area to bed volume greater than about 1 cm^{-1}.

9. The system according to Claim 1, further comprising a heat source capable of increasing the vaporization of the solid source for vapor reactant.

10. The system according to Claim 1, further comprising a vessel containing the support medium, the system being configured to pulse a substantially plug flow residence time distribution of both the carrier gas and the vapor reactant through the vessel.

11. An atomic layer deposition (ALD) semiconductor processing system comprising:

a source of carrier gas;

a support medium onto which a solid source for vapor reactant is coated, the support medium being configured to guide the carrier gas in a generally non-parallel contact path, the support medium being further configured to facilitate the saturation of the carrier gas over each of a plurality of pulses; a reaction chamber located downstream of the support medium; and a pulsing mechanism configured to provide pulses of saturated carrier gas from the support medium to the reaction chamber, wherein the support medium is further configured to facilitate the repeated saturation of the carrier gas with the vapor reactant for greater than 100,000 pulses, each pulse lasting for about 0.1-10 seconds.

12. The atomic layer deposition (ALD) system according to Claim 11, wherein the support medium is further configured to facilitate the repeated saturation of the carrier gas with the vapor reactant when the time between successive pulses of the vapor reactant is greater than 0.400 seconds and less than about 10 seconds.

13. The atomic layer deposition (ALD) system according to Claim 11, wherein the support medium is further configured to guide the carrier gas through multiple generally non-parallel contact pathways.

14. A semiconductor processing system for fabricating a substrate comprising a plurality of flowable support elements onto which a solid source for vapor reactant is coated, the support elements being packed into a vessel and configured to guide the through the support elements in a tortuous contact path.

15. The system of Claim 14, wherein the support elements are further configured to facilitate the repeated saturation of gas exiting the vessel with the solid source for a vapor reactant for greater than 100,000 pulses, each pulse lasting for about 0.1-10 seconds with the time between successive pulses being no less than 30 seconds.

16. The system of Claim 14, further comprising:

a carrier gas source located upstream of the inlet port; and

a chemical vapor deposition (CVD) chamber located downstream of the outlet port.

17. The system of Claim 14, further comprising:

a carrier gas source located upstream of the inlet port; and

an atomic layer deposition (ALD) reactor located downstream of the outlet port.

18. A sublimation apparatus comprising:

a sublimation vessel;

an inlet port leading into the vessel;

an outlet port leading out of the vessel;

a solid source for vapor reactant contained within the vessel; and

a support medium having a coating of a solid source for vapor reactant, the coating having a ratio of exposed surface area to support medium volume greater than about 0.1 cm^{-1}.

19. The apparatus according to Claim 18, configured to draw the vapor reactant through the support medium and out of the outlet port via convective transfer.

20. The apparatus according to Claim 18, configured to guide a carrier gas through the support medium.

21. The apparatus according to Claim 18, wherein the support medium is configured to be substantially stationary once inserted into the sublimation vessel.

22. The apparatus according to Claim 18, further including a manifold located in the sublimation vessel, the manifold being configured to distribute a carrier gas across the vessel to contact the coated support medium.

23. The apparatus according to Claim 18, wherein the sublimation vessel is configured to have the inlet port and the outlet port located at opposite ends of the vessel.

24. The apparatus according to Claim 23, wherein the sublimation vessel is a cylinder.

25. The apparatus according to Claim 18, wherein the support medium is formed from flowable support elements packed into the vessel.

26. The apparatus according to Claim 25, wherein the support elements have shapes selected from a group consisting of beads, cylinders, filaments and rings.

27. The apparatus according to Claim 18, wherein the support medium is a fixed support medium.

28. The apparatus according to Claim 27, wherein the fixed support medium coated with solid source for vapor reactant is selected from the group consisting of a tube, a coiled tube, a bundle of tubes, a filter, and a multiple intersecting plate structure.

29. The apparatus according to Claim 27, wherein the fixed support medium is configured to substantially conform to the shape of the sublimation vessel.

30. The apparatus according to Claim 18, wherein the support medium is configured to guide the carrier gas through a generally tortuous contact path.

31. The apparatus according to Claim 18, wherein the support medium is a substantially inert, thermally conductive support medium.

32. The apparatus according to Claim 31, wherein the support medium comprises a material selected from the group consisting of alumina (Al_2O_3), fused silica, stainless steel, hastelloy, nickel, silicon carbide (SiC), and boron nitride (BN).

33. The apparatus according to Claim 18, *further comprising a heat source capable* of increasing the vaporization of the solid source for vapor reactant.

34. The apparatus according to Claim 18, wherein the solid source for vapor reactant coating is hafnium chloride ($HfCl_4$).

35. The apparatus according to Claim 18, wherein the solid source for vapor reactant coating is zirconium chloride ($ZrCl_4$).

36. A method of employing a vapor reactant for substrate processing comprising:

introducing a carrier gas into a vessel through an inlet port;

guiding the carrier gas to contact sufficient vapor reactant from a solid source material in order to repeatedly saturate the carrier gas with the vapor reactant, the saturation of the carrier gas continuing for greater than 100,000 pulses of carrier gas, each pulse lasting for greater than about 0.1 seconds; and

routing the carrier gas out of the vessel through an outlet port.

37. The method according to Claim 36, wherein routing the carrier gas out of the vessel further comprises pulsing the carrier gas out of the outlet port with the time between successive pulses being no more than about 30 seconds.

38. The method according to Claim 36, wherein guiding comprises flowing the carrier gas through a support medium coated with the solid source material.

39. The method according to Claim 38, further comprising inserting the support media into a substantially stationary position within the sublimation vessel.

40. The method according to Claim 36, wherein guiding the carrier gas comprises guiding the carrier gas in a generally helical contact path as defined by a flow guide.

41. The method according to Claim 36, further comprising channeling the carrier gas carrying the solid source vapor to a chemical vapor deposition (CVD) reactor.

42. The method according to Claim 36, further comprising:

pulsing the carrier gas carrying the vapor reactant to an atomic layer deposition (ALD) reaction chamber;

removing any excess vapor reactant from the reaction chamber;

pulsing the reaction chamber with a second reactant; and

removing any excess second reactant from the reaction chamber.

43. The method according to Claim 36, further comprising pouring a plurality of support elements through a fill port in the sublimation vessel, the support elements being coated with the solid source material.

44. A sublimation apparatus for producing a reactant vapor for flowing through a reaction chamber comprising:

a sublimation vessel;

a bed of a solid source for the vapor reactant, the solid source bed contained within the vessel;

a carrier gas guidance structure with which the solid source is directly in contact, the guidance structure being configured to guide the carrier gas to contact the vapor reactant from the bed of the solid source by providing a substantially segregating and winding contact pathway for a carrier gas;

a vessel inlet port located at the beginning of the unitary contact pathway provided by the carrier gas guidance structure; and

a vessel outlet port located at the end of the unitary contact pathway provided by the carrier gas guidance structure, wherein the carrier gas guidance structure is configured to ensure contact of the carrier gas with the vapor reactant along a the substantially segregated and winding contact pathway having a length greater than about 2.5 times a linear distance measured from the inlet port to the outlet port.

45. The sublimation apparatus according to Claim 44, wherein the solid source for vapor reactant forming the sublimation bed is in the form of a solid powder.

46. The sublimation apparatus according to Claim 45, wherein the guidance structure is a flow guide configured to extend from a sublimation vessel floor to a sublimation vessel ceiling.

47. The sublimation apparatus according to Claim 46, wherein the bed is a single continuous bed and the flow guide is configured to guide the carrier gas in a helical path in contact with the bed of the solid source.

48. The sublimation apparatus according to Claim 44, wherein the guidance structure is configured to guide the carrier gas in a helical path, the guidance structure comprising a plurality of levels within the vessel with each level containing a batch of the solid source for vapor reactant.

49. The sublimation apparatus according to Claim 48, wherein the guidance structure further comprises a plurality of stacked trays partially defining levels of the helical path.

50. The sublimation apparatus according to Claim 49, wherein at least one of the plurality of stacked trays is a guided tray comprising at least one substantially circular pathway, the guided tray being configured to guide the carrier gas at least one lap of at least about 200° around the guided tray before channeling the carrier gas to an adjacent tray.

51. The sublimation apparatus according to Claim 49, wherein at least one of the plurality of stacked trays is a guided tray comprising a secondary partial divider which partially defines at least two substantially circular pathways in the guided tray, the secondary partial divider in combination with tray sidewalls being configured to guide the carrier gas

about two laps around the guided tray before channeling the gas to an adjacent stacked tray, each lap being at least 200° around the guided tray.

52. The sublimation apparatus according to Claim 51, wherein the secondary partial divider defines at least two substantially circular pathways around the guided tray, the guided tray further comprising at least two substantially circular pathways configured to channel the carrier gas in substantially opposite directions relative to one another.

53. The sublimation apparatus according to Claim 44, further comprising a vessel containing the support medium, the system being configured to pulse a substantially plug flow residence time distribution of both the carrier gas and vapor reactant through a vessel from a vessel outlet.

54. A method of processing a substrate comprising:

producing a pulse of a carrier gas substantially saturated with a precursor vapor by contacting the carrier gas with a solid precursor source;

injecting the pulse of the carrier gas substantially saturated with precursor vapor into a reaction chamber;

purging the pulse from the chamber with an inert gas; and

depositing the precursor onto the substrate so that the substrate is substantially saturated with the precursor,

wherein injecting, purging, and depositing comprise a cycle which is repeated for at least 5 cycles with no greater than 30 seconds between the successive injecting of the pulses of the carrier gas substantially saturated with the precursor vapor.

55. The method of Claim 54, wherein producing the pulse of the carrier gas substantially saturated with precursor comprises affecting a vapor pressure between 0.1 and 100 Torr.

56. The method of Claim 54, wherein producing the pulse of the carrier gas substantially saturated with the precursor vapor comprises contacting the carrier gas with the solid precursor along a carrier gas contact pathway which is at least twice as long as the distance between a carrier gas inlet and a carrier gas outlet of a vessel containing the solid precursor source.

57. The method of Claim 54, wherein producing the pulse of carrier gas substantially saturated with the precursor vapor comprises contacting the carrier gas with the solid precursor along a segregated and winding gas contact pathway.

58. The method of Claim 54, wherein producing the pulse of carrier gas substantially saturated with the precursor vapor comprises contacting the carrier gas with a solid precursor coating of a support medium.

59. The method of Claim 54, wherein producing the pulse comprises isolating the solid source after each injection by temporarily preventing the carrier gas substantially saturated with precursor vapor from exiting a vessel containing the solid precursor source.

60. A method of performing an atomic layer deposition (ALD) process to deposit a layer on a substrate surface comprising:

contacting a carrier gas with a precursor vapor from a solid precursor source in a sublimation vessel so that the carrier gas is substantially saturated with the precursor vapor;

channeling the substantially saturated carrier gas from the vessel and through a conduit to a substrate processing chamber;

pulsing the substantially saturated carrier gas into the substrate processing chamber; and

stopping the flow of substantially saturated carrier gas from the vessel,

purging the substantially saturated carrier gas from the chamber with a substantially inert gas,

wherein pulsing, stopping, and purging comprise a cycle, the cycle being repeated at least twice during the deposition of the layer.

61. The method of Claim 60, further comprising contacting a second carrier gas with a second precursor vapor from a second solid precursor source so that the carrier gas is substantially saturated with the second precursor vapor.

62. The method of Claim 60, wherein a recharge period of the sublimation vessel is greater than 0.400 seconds and less than 30 seconds between stopping the flow and a next pulsing of the substantially saturated carrier gas into the substrate processing chamber.

63. The method of Claim 60, wherein stopping the flow comprises isolating the sublimation vessel from the processing chamber for greater than 0.400 and less than 10 seconds between pulses.

64. The method of Claim 63, wherein a duration of each pulsing in a cycle comprises at least 0.1-10 seconds.

65. The method of Claim 63, wherein each pulse is substantially saturated for at least 100,000 cycles.

66. The method of Claim 65, wherein each pulse is substantially saturated for at least 500,000 cycles.

67. The method of Claim 63, wherein after no more than each cycle is completed, the substrate surface is substantially saturated with adsorbed species of the precursor vapor.

68. The method of Claim 60, wherein about one monolayer of the precursor is deposited per cycle.

69. The method of Claim 60, wherein each cycle deposits about 1-5 Å.

70. The method of Claim 60, wherein channeling the substantially saturated carrier gas from the vessel comprises flowing a substantial plug flow through the vessel to a vessel outlet.

71. The method of Claim 60, wherein contacting a carrier gas with a precursor vapor from a solid precursor source in a sublimation vessel comprises producing a substantial plug flow residence time distribution of flow in the vessel.

72. The method of Claim 71, wherein pulsing the substantially saturated carrier gas into the substrate processing chamber further comprises flowing the substantial plug flow through the chamber

73. The method of Claim 71, wherein producing the pulse of the carrier gas substantially saturated with the precursor vapor comprises contacting the carrier gas with the solid precursor source along a convoluted carrier gas contact pathway.

74. The method of Claim 73, wherein producing the pulse of the carrier gas substantially saturated with the precursor vapor comprises contacting the carrier gas with the solid precursor source that coats a support medium.

75. A sublimation apparatus for producing a reactant vapor for flowing through a reaction chamber comprising:

a sublimation vessel;

a bed of a solid source for the vapor reactant, the solid source bed contained within the vessel;

a vapor guidance structure with which the solid source is directly in contact, the guidance structure being configured to guide the vapor reactant from the bed of the solid source by providing a substantially segregating and convoluted contact pathway for the vapor reactant;

a vessel inlet port located at the beginning of the unitary contact pathway provided by the guidance structure; and

a vessel outlet port located at the end of the unitary contact pathway provided by the guidance structure, wherein the guidance structure is configured to transfer the vapor reactant via convective transfer along the substantially segregated and winding contact pathway having a length greater than about 2.5 times a linear distance measured from the inlet port to the outlet port.